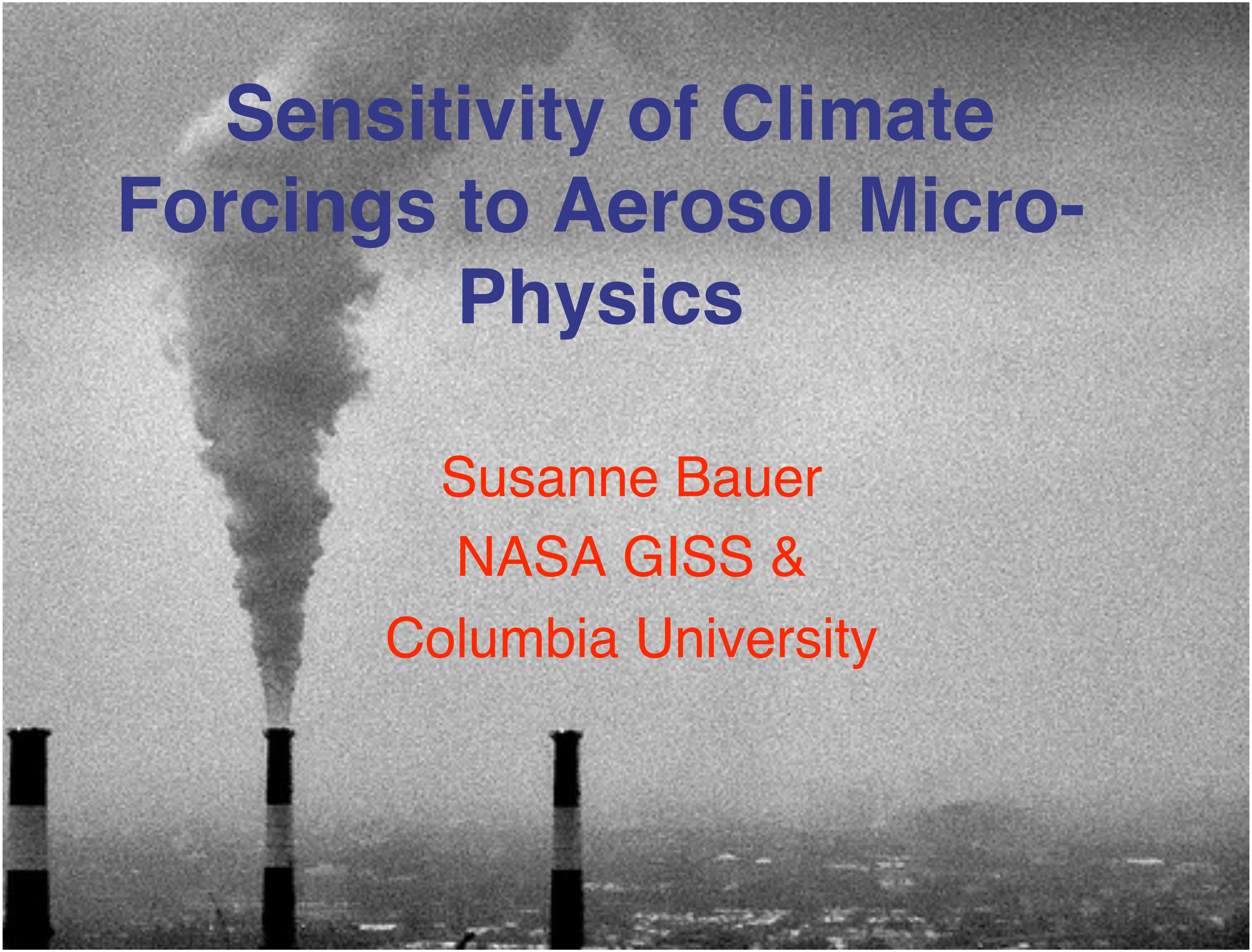


Sensitivity of Climate Forcings to Aerosol Micro-Physics

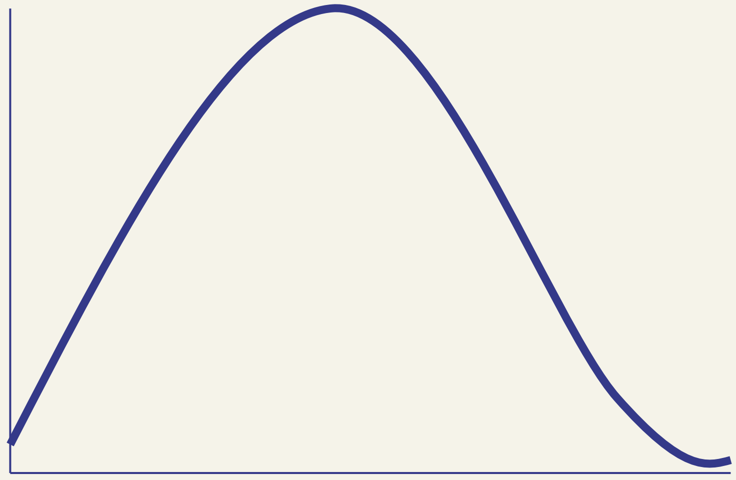
Susanne Bauer
NASA GISS &
Columbia University

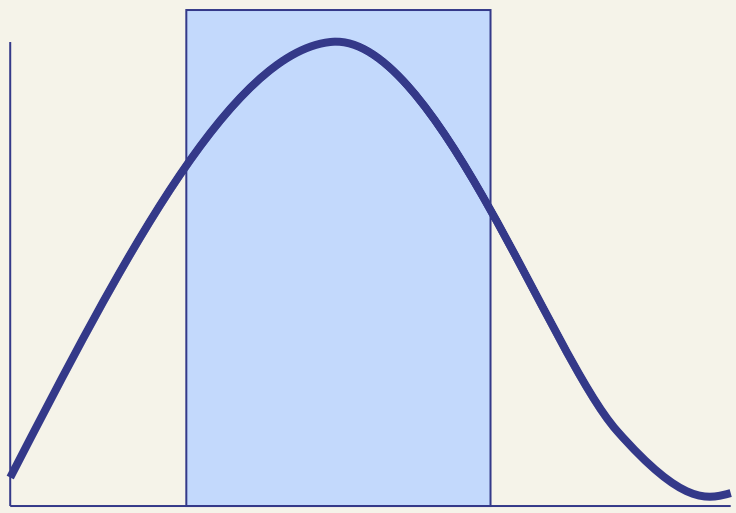
WHY *?

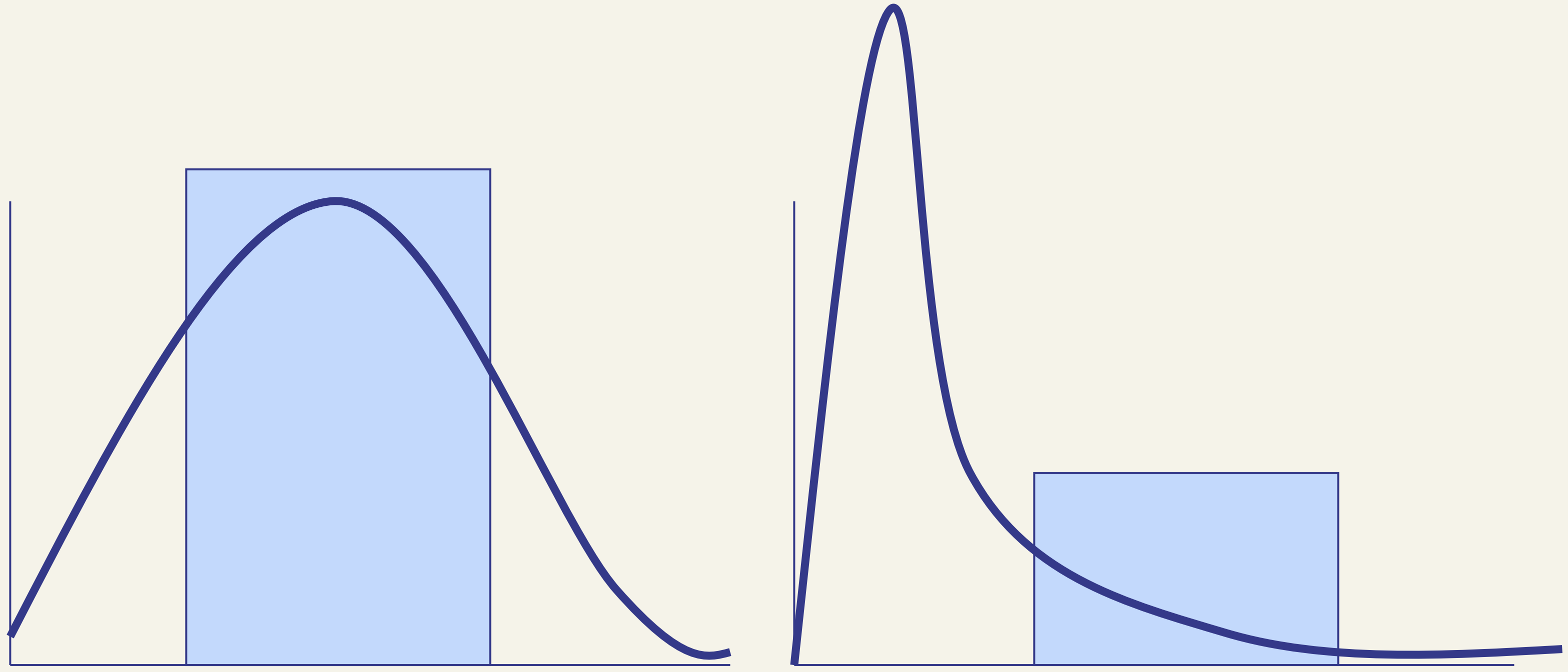
- Aerosol Size Distributions
- Aerosol Mixing State
- Processes: New Particle Formation, Condensation, Coagulation, Thermodynamics, CCN Activation
- Aerosol Direct Forcing
- Indirect Aerosol Effect

*** Isn't the problem already complicated enough?**

Aerosol Size Distribution







1) Bin Scheme

Sectional Methods are very expansive especially when particle dynamic is considered.

2) Modal Scheme (Mass and Number)

Approximation of the size distribution by lognormal distributions.
The size distributions has to be known.

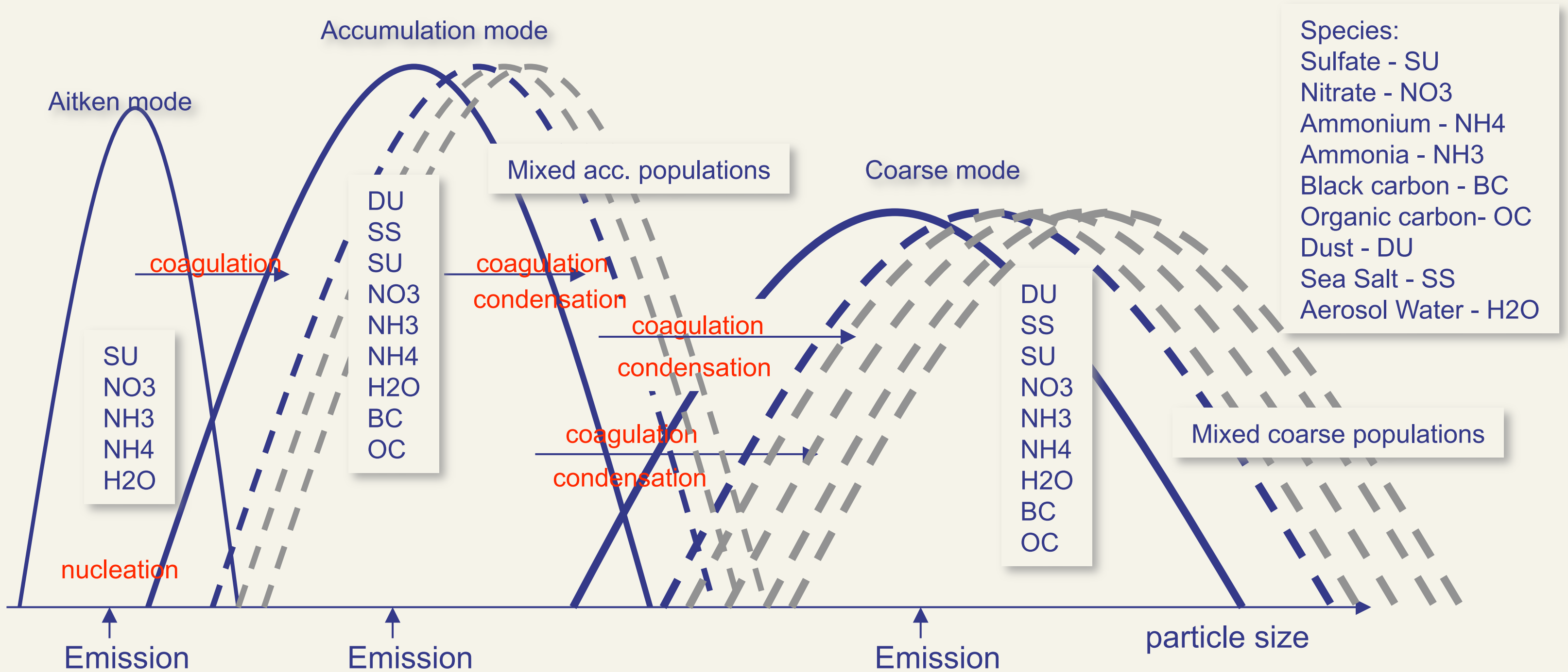
3) Quadrature Method of Moments (QMOM) (McGraw, 1997):

QMOM provides a computationally efficient statistically-based alternative to modal and sectional methods for aerosol simulation

- Aerosols are represented by the moments of the size distribution.
- QMOM does not need any a priori specific information on size distribution.
- QMOM keeps track of the average particle size distribution to obtain a set of equations for various moments.
- Lower moments contain enough information for aerosol application.

MATRIX

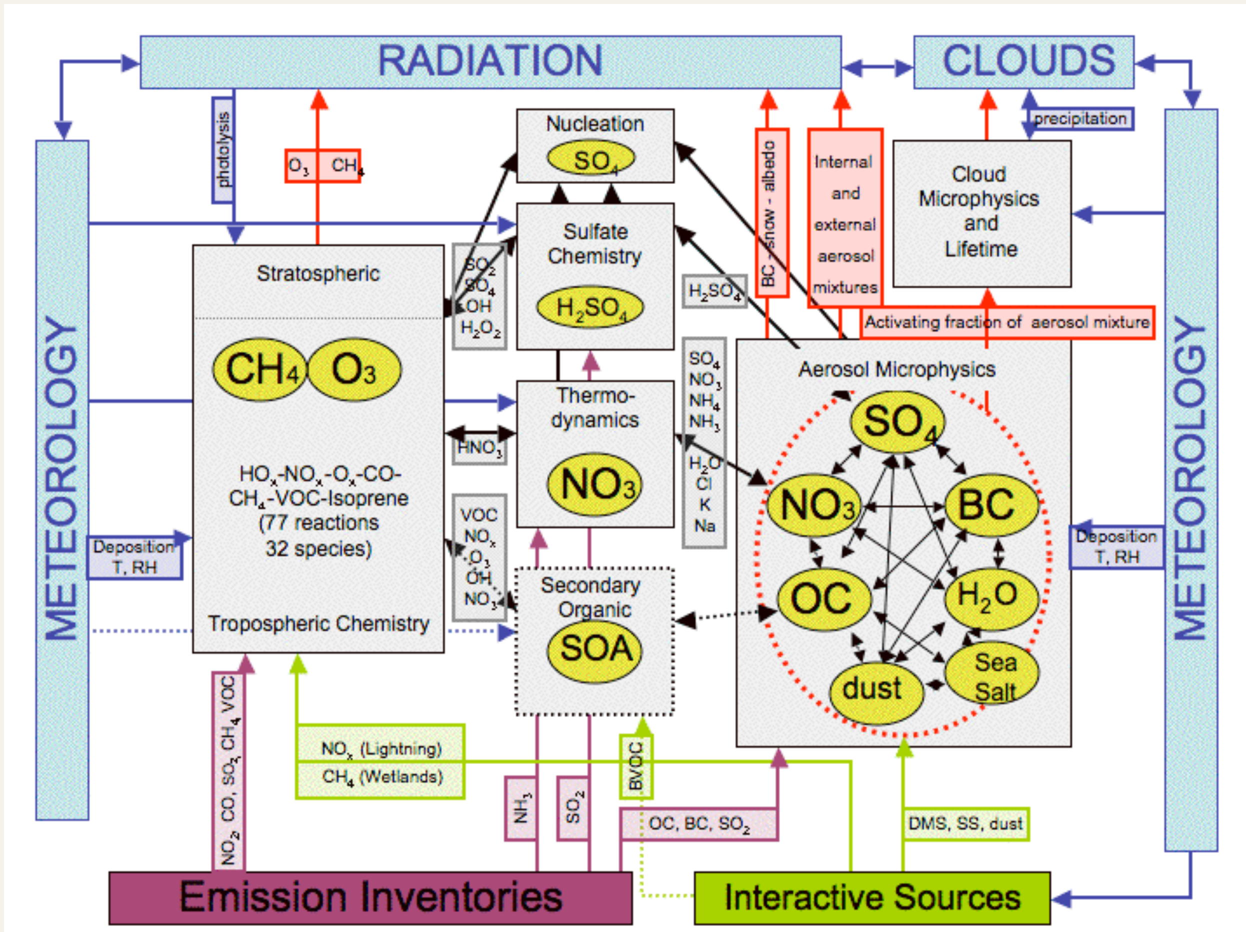
Aerosol Microphysical Model based on the Methods of Moments
Bauer et al. ACP 2008



•Partitioning of semi volatile species: EQSAM 3 (Metzger et al. 2006)
•Droplet activation: Abdul Razzak and Ghan(1998, 2000)

GISS Earth System Model

GISS climate model (modelE) *Schmidt et al. 2006*
Fully coupled ocean-atmosphere climate model
Including gas and aerosol phase chemistry



Overview

- Modeling Aerosol Microphysics
- MATRIX - new GISS aerosol model
- Sensitivity experiments of microphysical processes:

  1 - Effects of Mixed Aerosol Populations on Forcings

  2 - Condensation / Coagulation and Dependence on Emission Size Information

  3 - Nucleation
- Summary and Outlook

Impact of Mixing State on Optical Properties

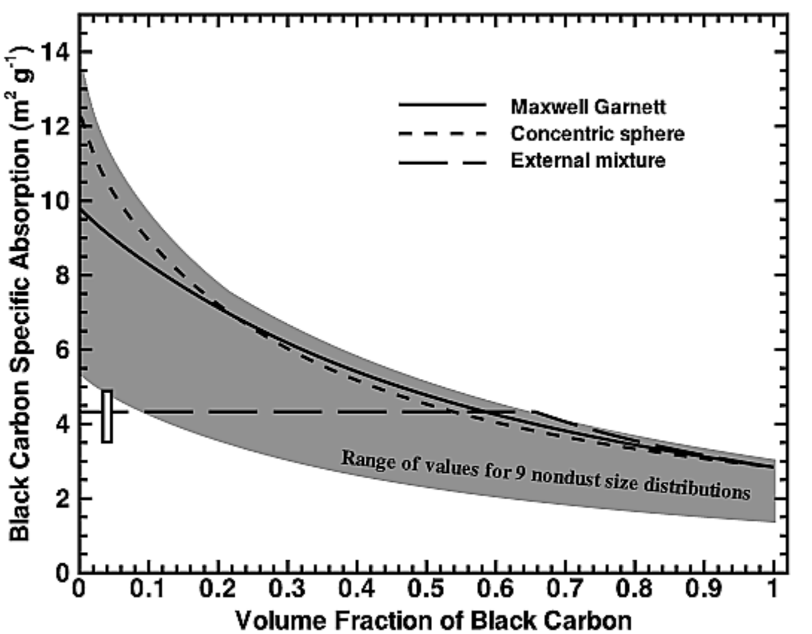
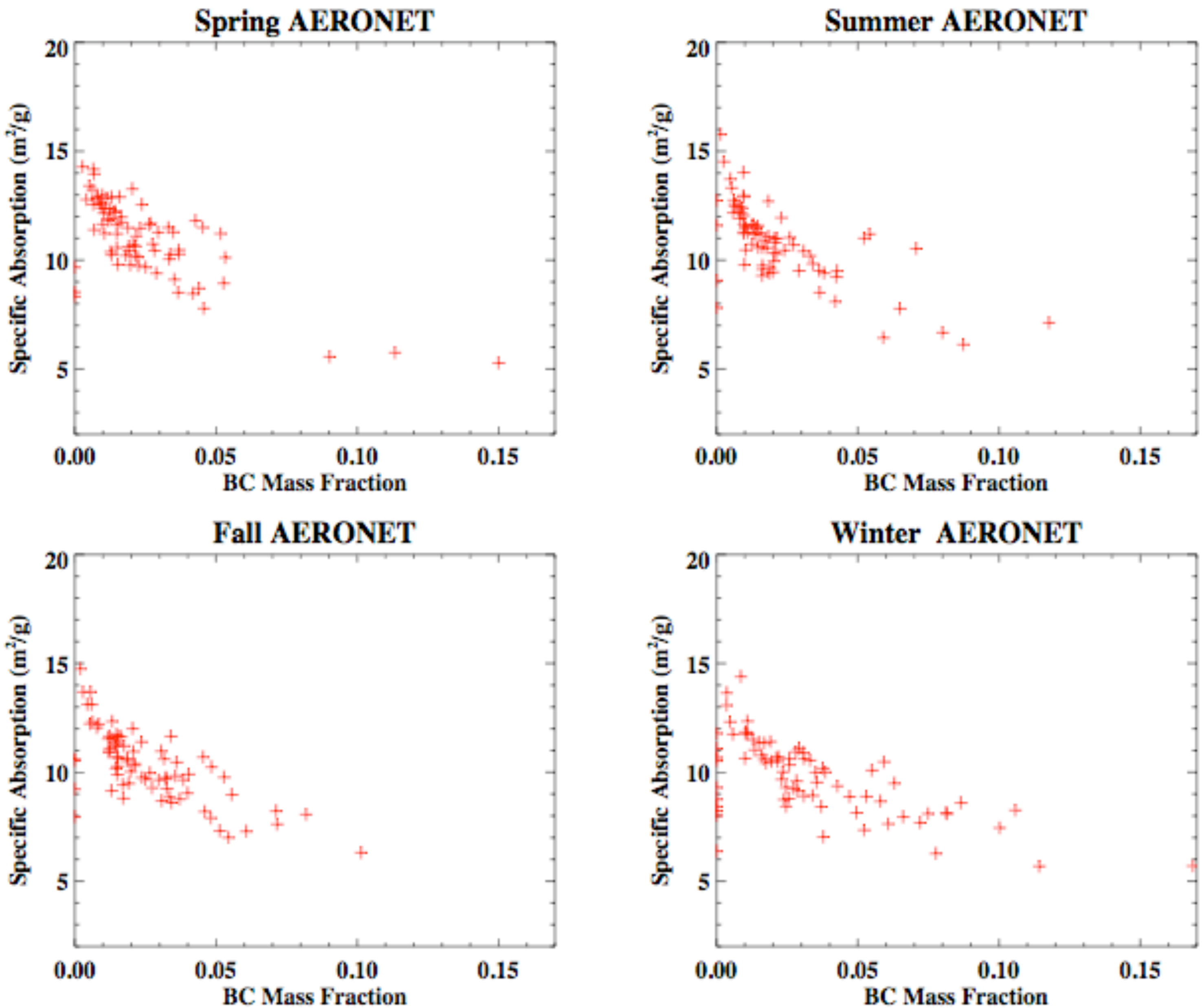


Figure 6. from *Schuster et al (2005)* Black carbon specific absorption (λ = 0.55 μm) inferred from size distribution climatologies in the work of Dubovik et al. [2002] and black carbon mixed with ammonium sulfate. The shaded area indicates the range of results for internal mixture on nine nondust size distributions.

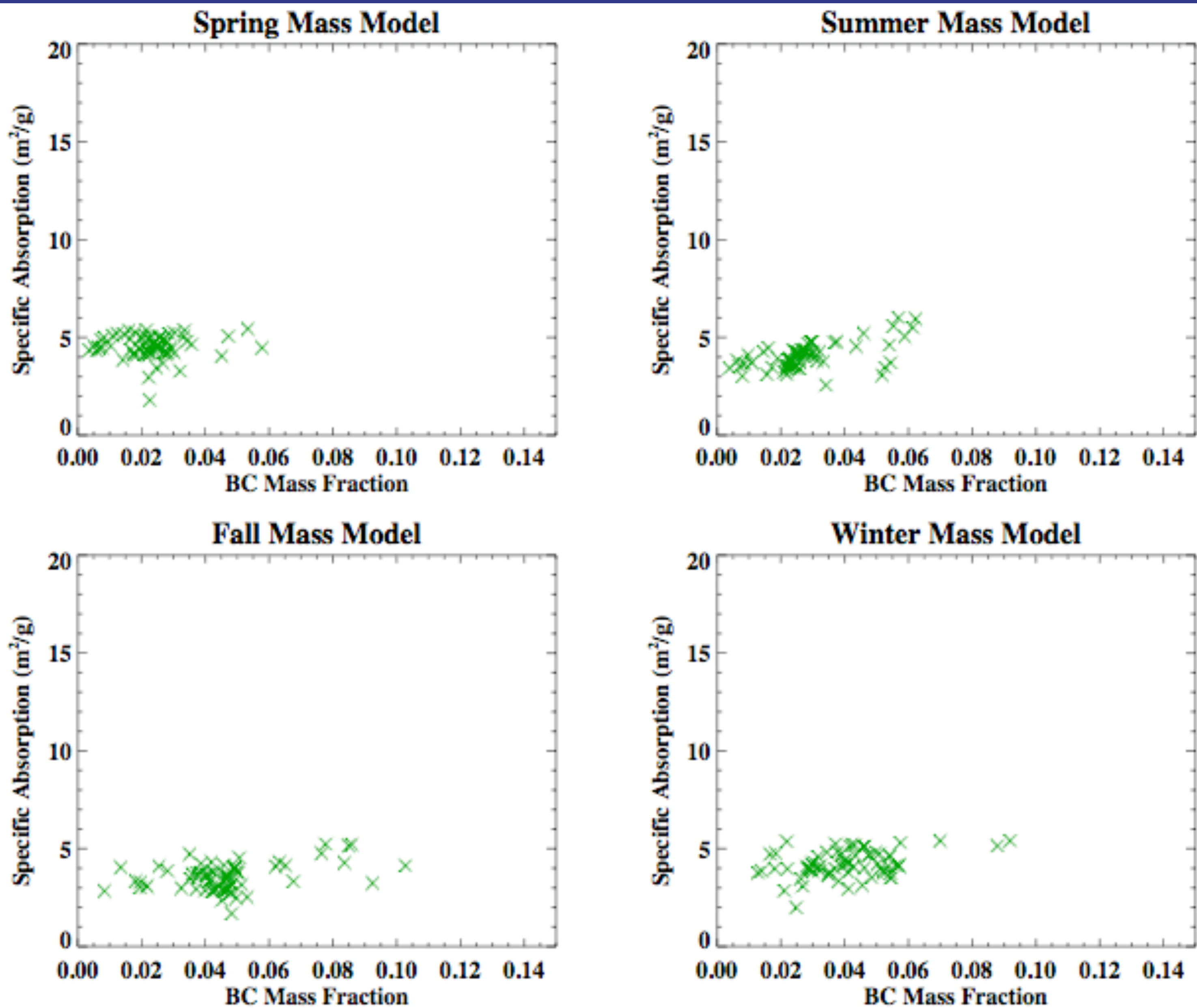
Sato and Hansen et al 2003: AERONET - BC study

BC effect (due to internal mixing) causes a much larger climate warming
-> GISS model fix - BC mass in forcing calculations multiplied by 3.

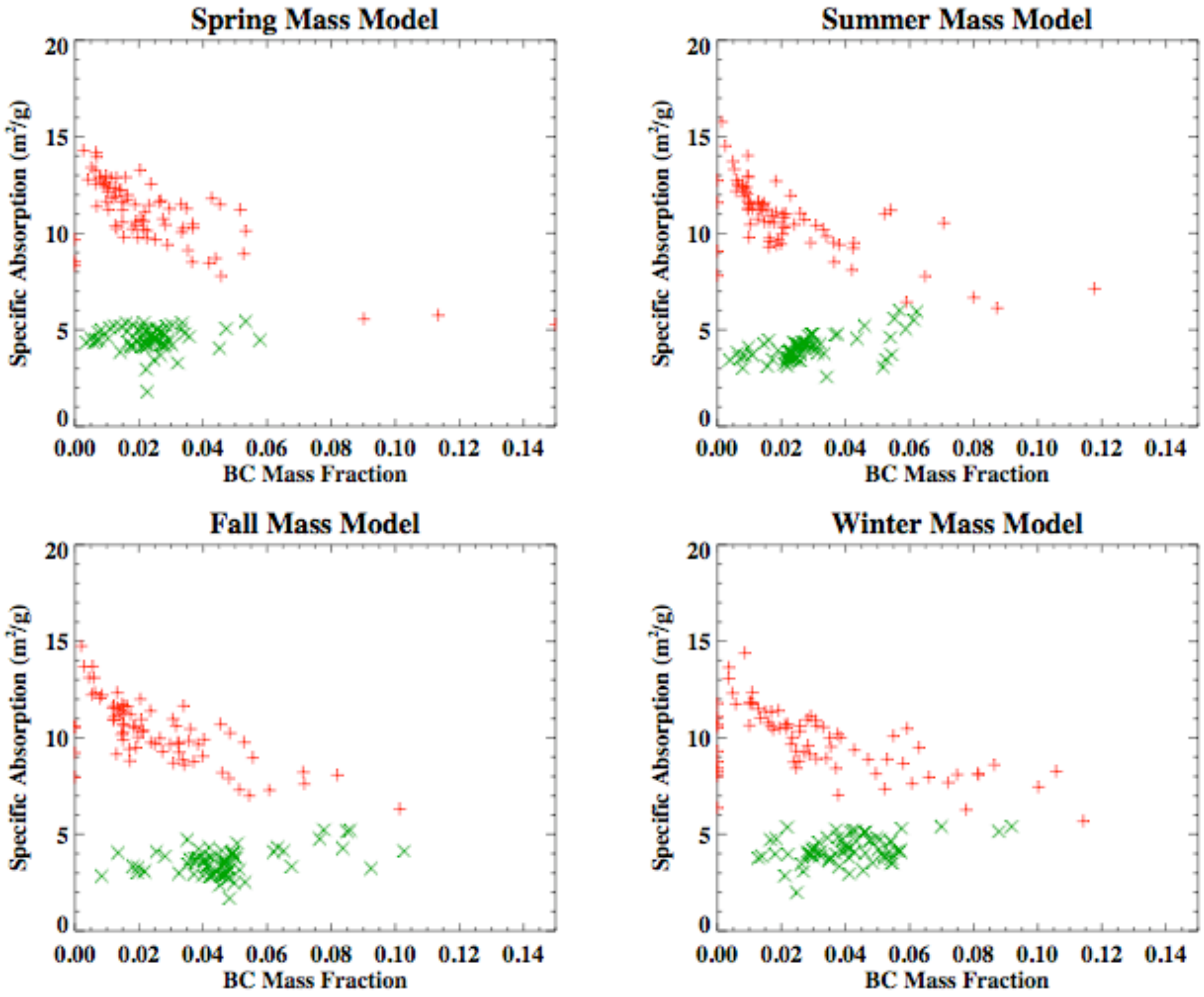
AERONET data (Y 2000): Specific Absorption / BC Mass Fraction



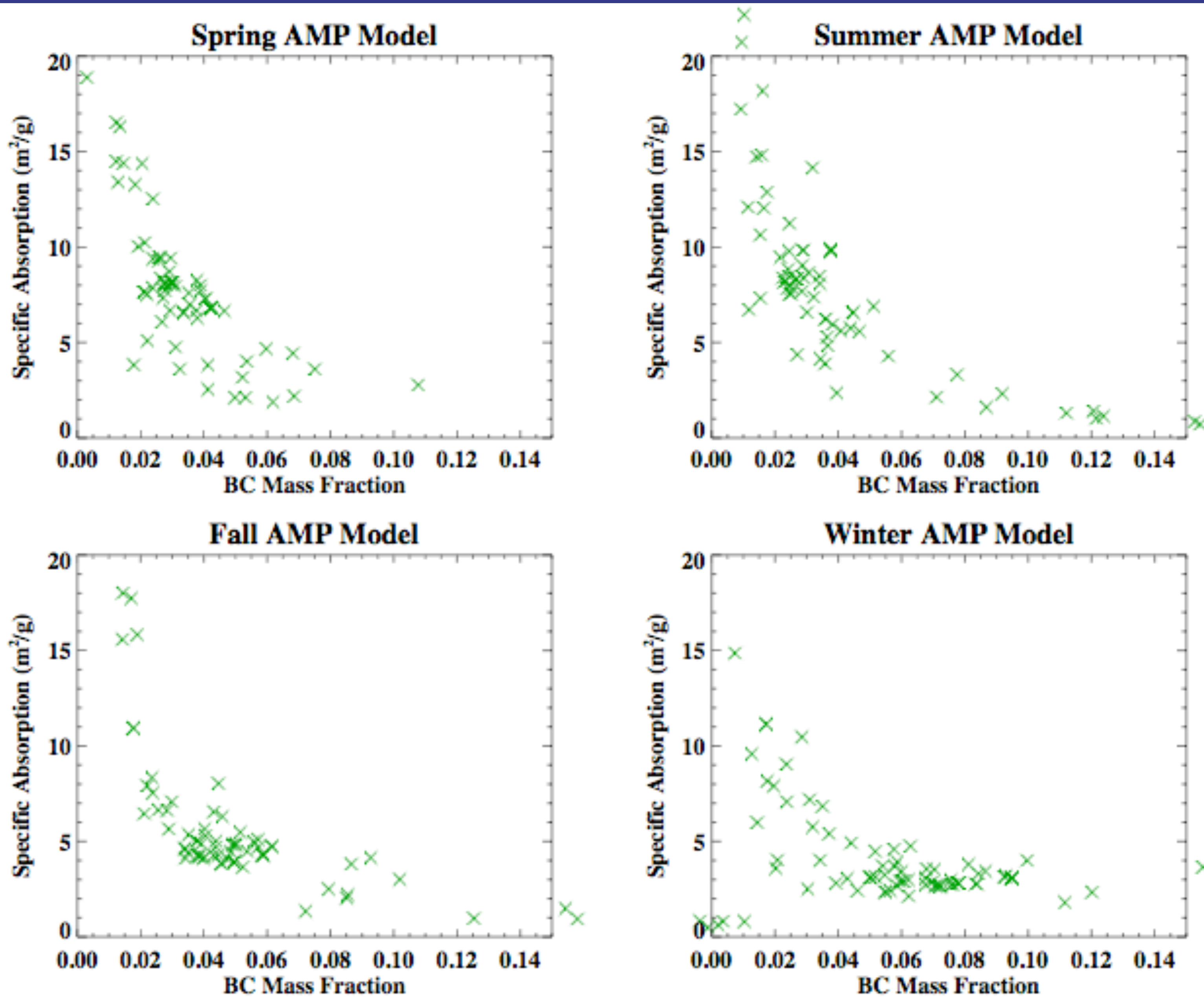
MASS model: Specific Absorption / BC Mass Fraction



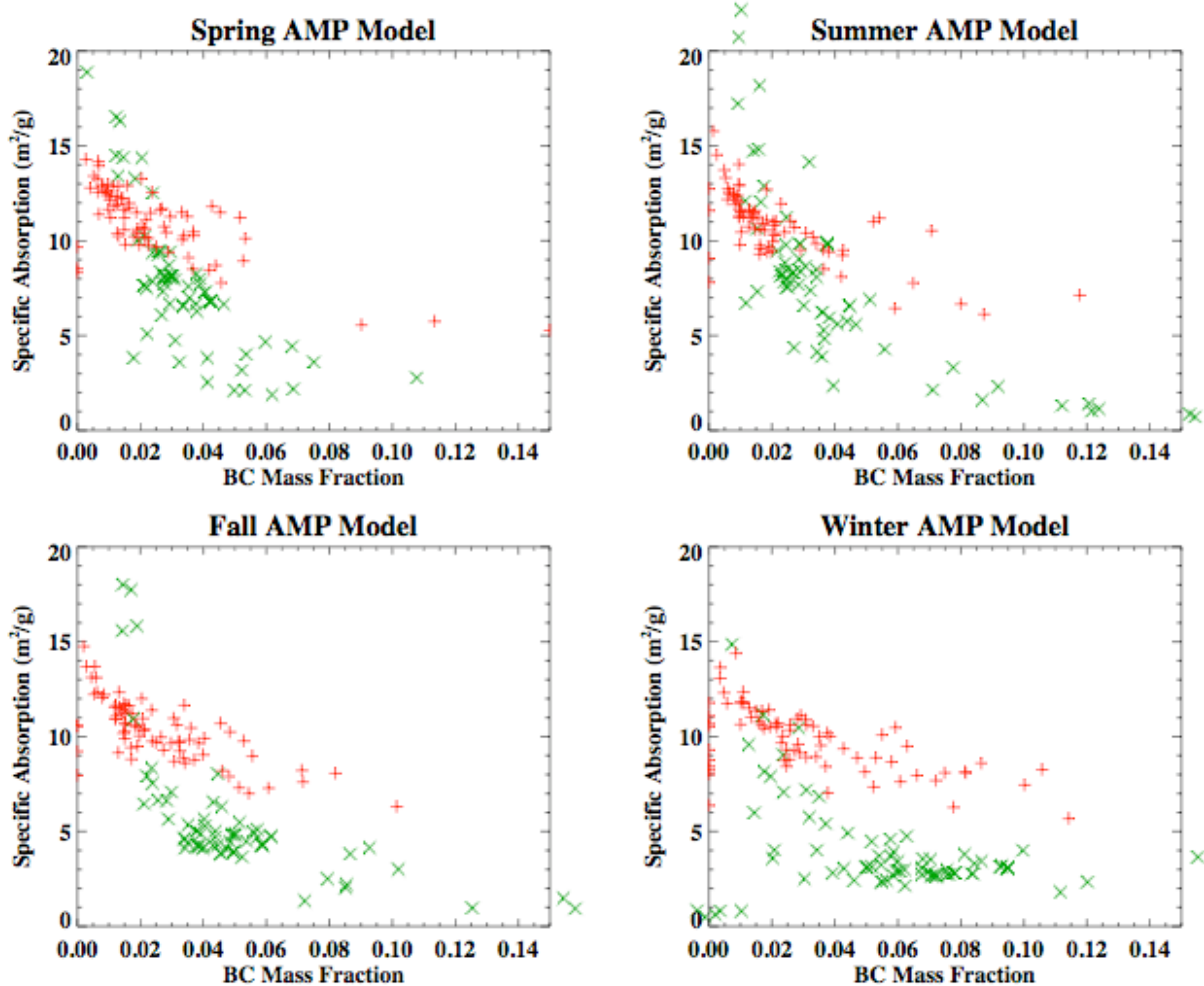
AERONET and MASS model: Specific Absorption / BC Mass Fraction



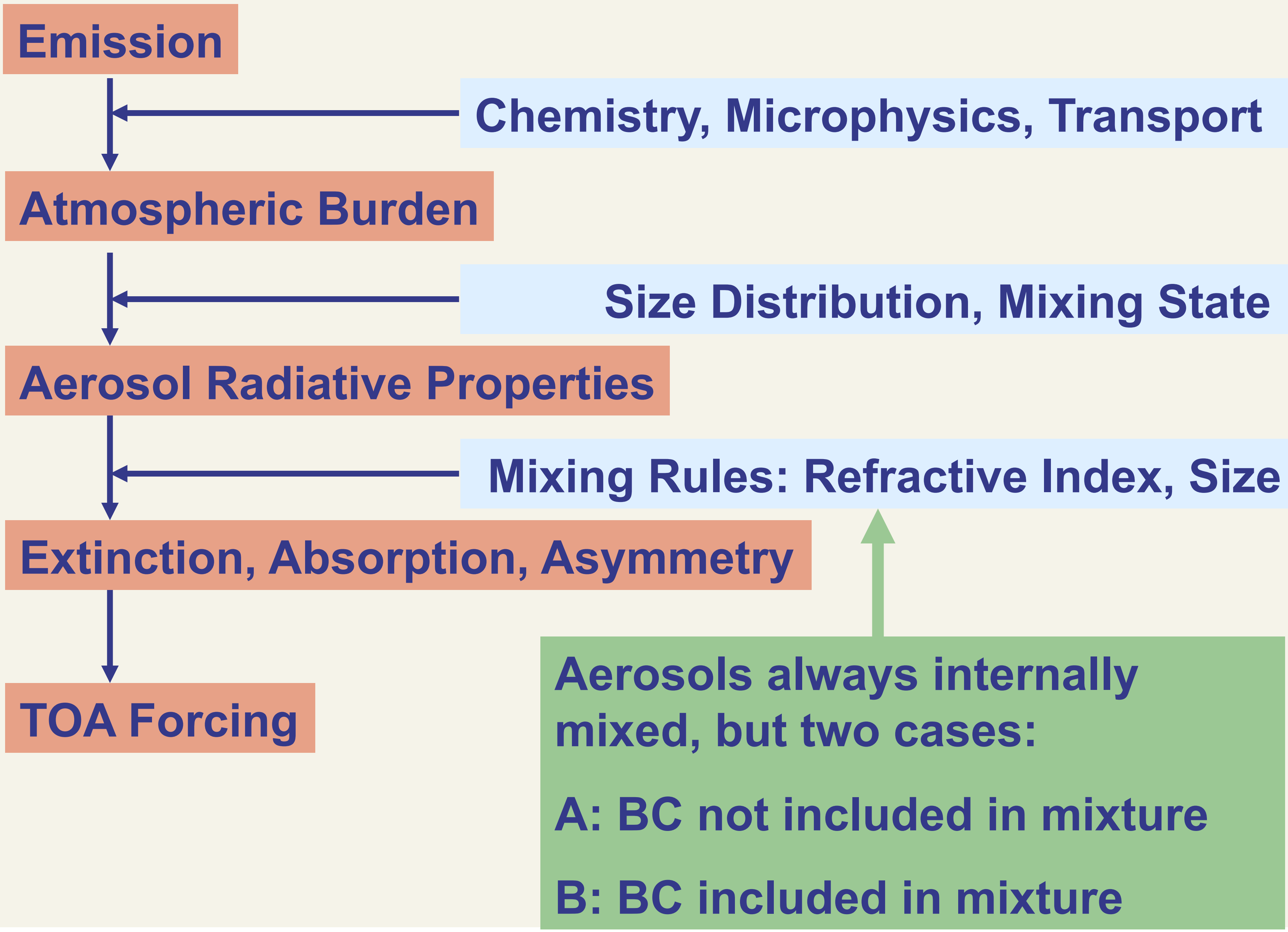
MATRIX: Specific Absorption / BC Mass Fraction



AERONET and MATRIX: Specific Absorption / BC Mass Fraction

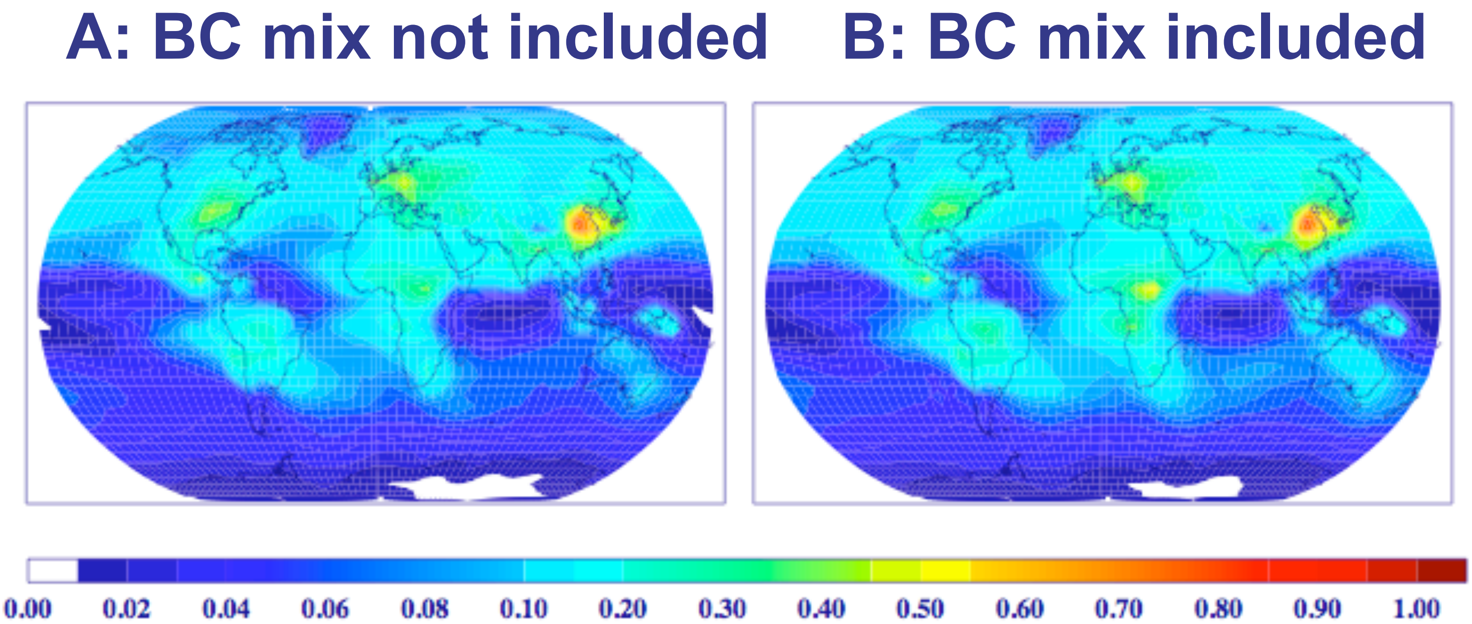


Experiment Setup: Internal versus external BC mixing state



Extinction Optical Thickness at 550nm

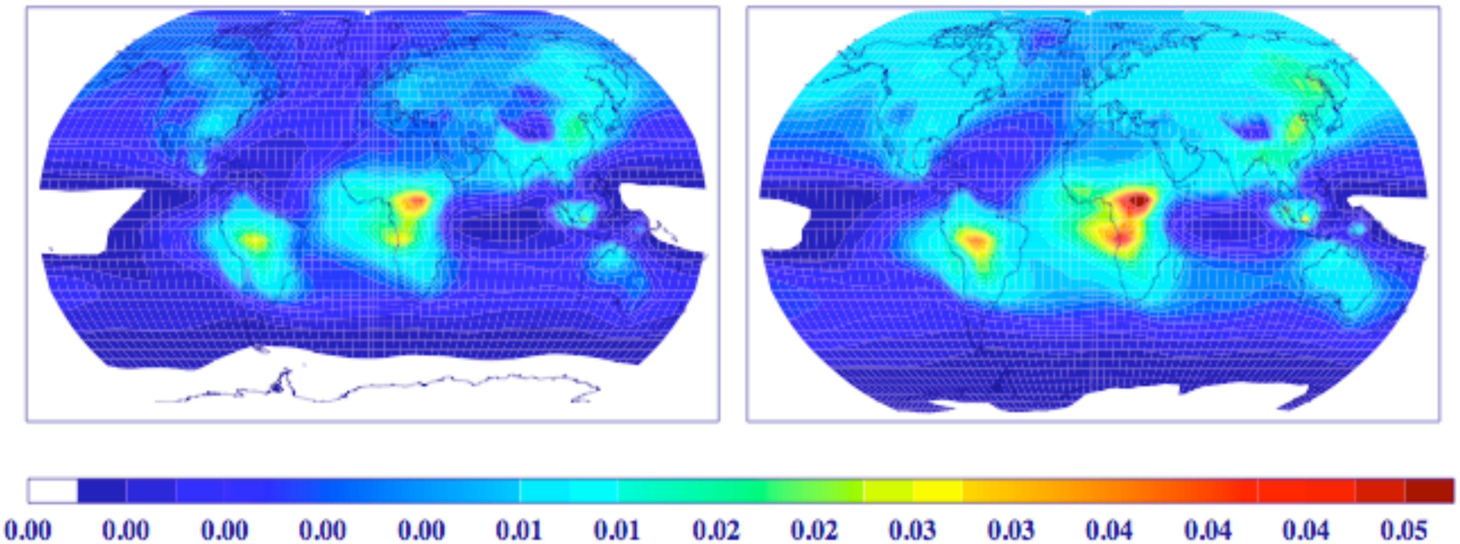
(Species: SO_4, NO_3, OC, BC)



Absorption Optical Thickness at 550nm

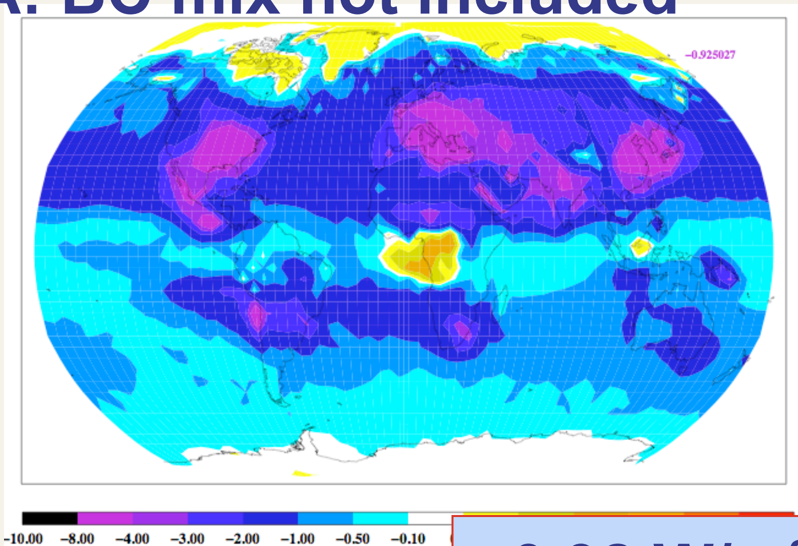
(Species: SO_4, NO_3, OC, BC)

A: BC mix not included **B: BC mix included**



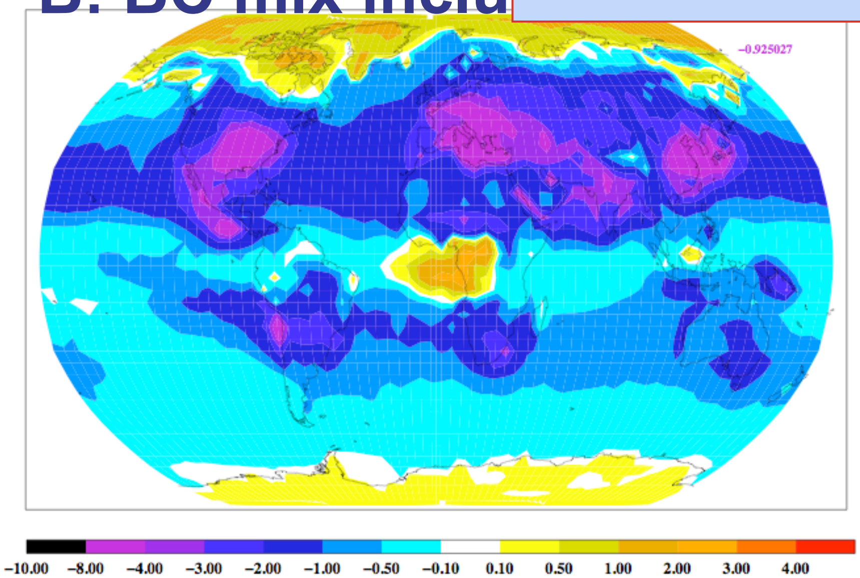
Top of Atm. Short Wave Radiative Forcing W/m²:
(Species: SO_4, NO_3, OC, BC)

A: BC mix not included

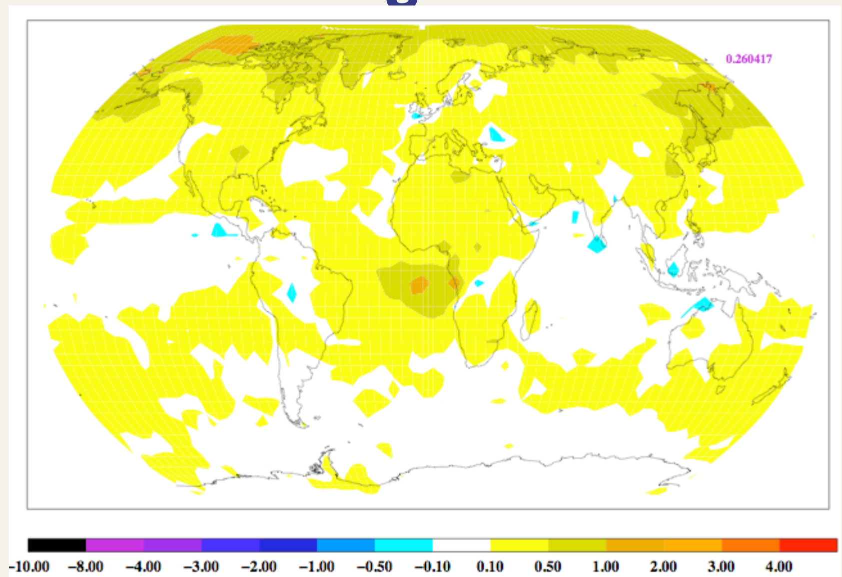


-0.92 W/m²

B: BC mix inclu



B-A:
BC mixing state effect

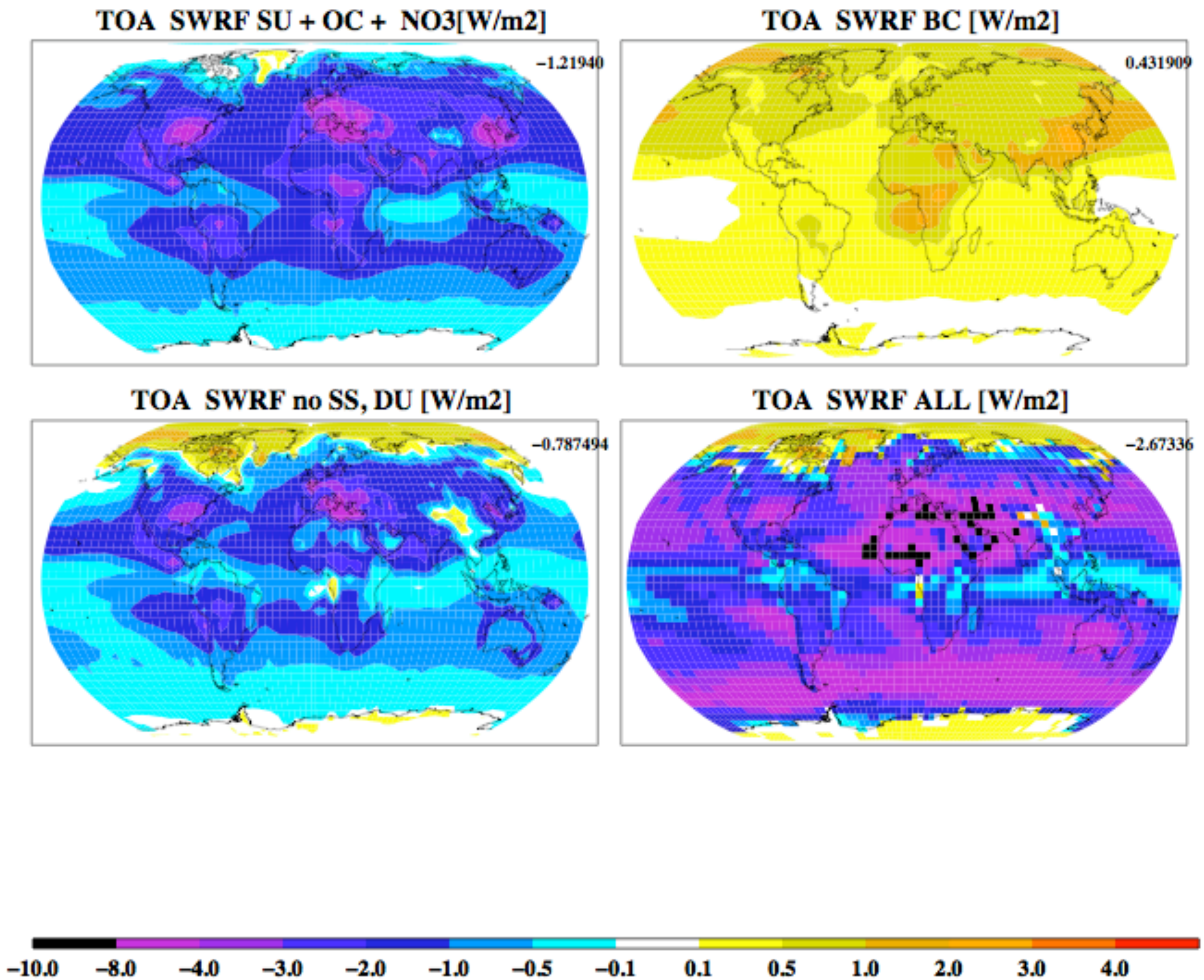


Mix effect: +0.26 W/m²

BC forcing as external mixture: +0.43 W/m²

(value taken from MASS based model)

Short Wave Radiative Forcing W/m^2:
MASS BASED SCHEME



Summary 3

Impact of BC mixing state on Direct Aerosol Radiative Forcing:

- It has been shown in many studies that internally mixed BC particle show increased absorption in comparison to externally mixed particles.
- The simulation of the mixing state of aerosols allows us to explicitly calculate that effect.
- Comparisons to AERONET show that MATRIX can represent the enhanced BC absorption in an internal mixture
- Simulations with MATRIX including and excluding the BC mixing state effect show that BC forcing is increased by 0.26 W/m^2.

- The largest increase in BC warming is seen over the Arctic, by 0.5 - 1. W/m2
- Further maxima are seen down-stream of East-Asia, and the African biomass burning area.